A wave physics approach to electronically steerable antennas

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With Jean-Baptiste Gros, Vladislav Popov & Mikhaïl Odit

Smallsat 2021
AUGUST 7-12, 2021

Beamforming at ultralow power, cost, weight and size, for space applications

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Who we are: A leading deeptech from CNRS

- **20 engineers/ researchers** (10 PhD, 5 nationalities)
- **8** patents + **2** ongoing
- **1** partnership with **CNRS**/ Institut **Langevin**
- **750k€** turnover 2020
- **>10** clients
- **>8M€** contracts

Our ORIGINS

Institut Langevin
ONDES ET IMAGES

WAVES AND IMAGING
FROM FUNDAMENTALS TO INNOVATION

- Created by Mathias FINK & Claude BOCCARA in 2009

- **120+** researchers
- **12+** successful startups

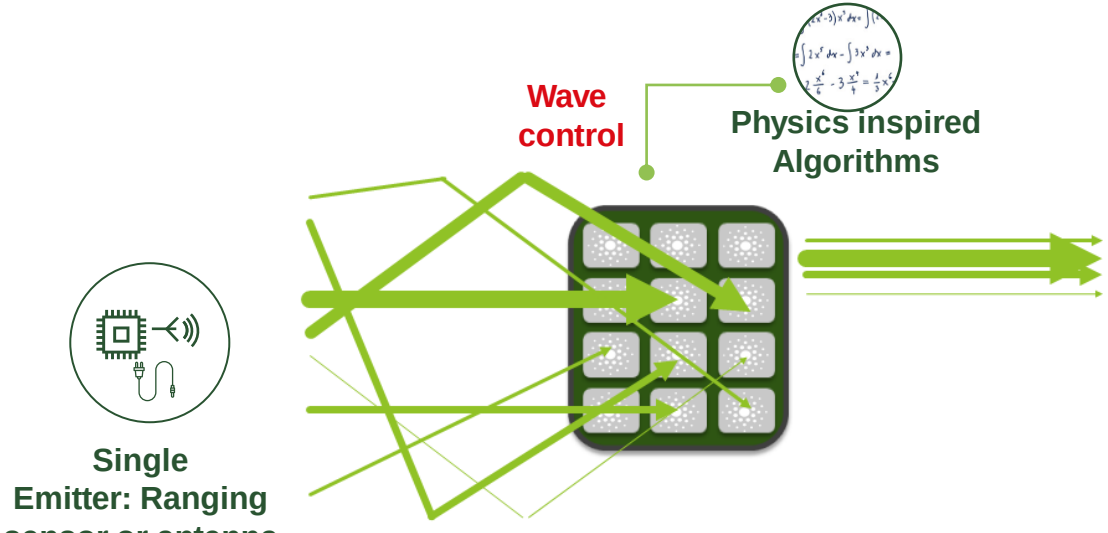
ESPCI PARIS

cnrs

> **From all startups from Institut Langevin, Greenerwave is the most disruptive and transversal.**
>
> ***Mathias Fink,***
> *co-founder, member of Académie des Sciences*

Controlling wave propagation rather than emission

SOFTWARE DEFINED APPROACH



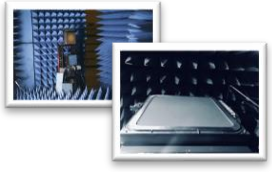
IOT, RFID

900 MHz

- Sensor detection
- Maintenance control
- Smart inventory
- …

CONNECTIVITY

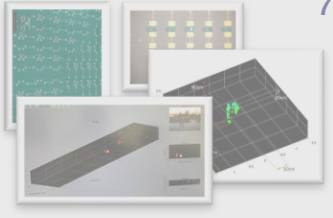
Beamforming antennas



X / Ku / Ka bands - 5G mmwave

- Fly and Drive away
- LOS reconfigurable antennas
- …

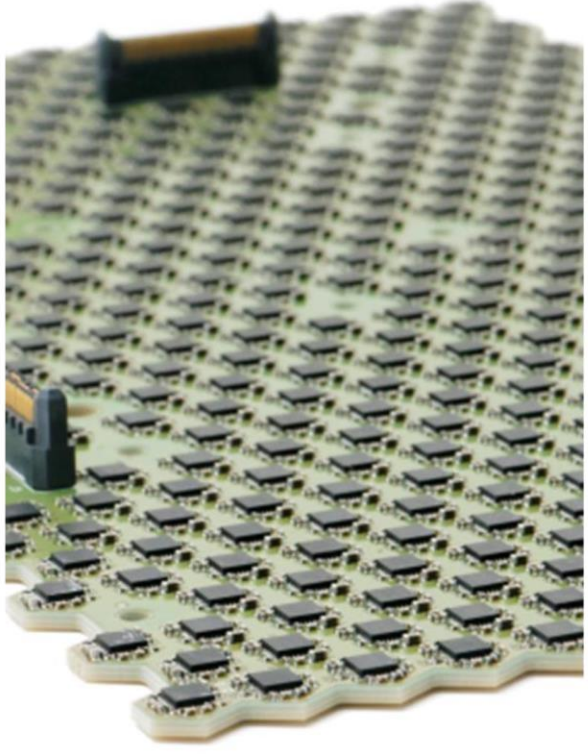
IMAGING RADAR



7 GHz, 24 GHz, 77 GHz

- Critical infrastructure surveillance
- UAV radars
- Health monitoring
- …

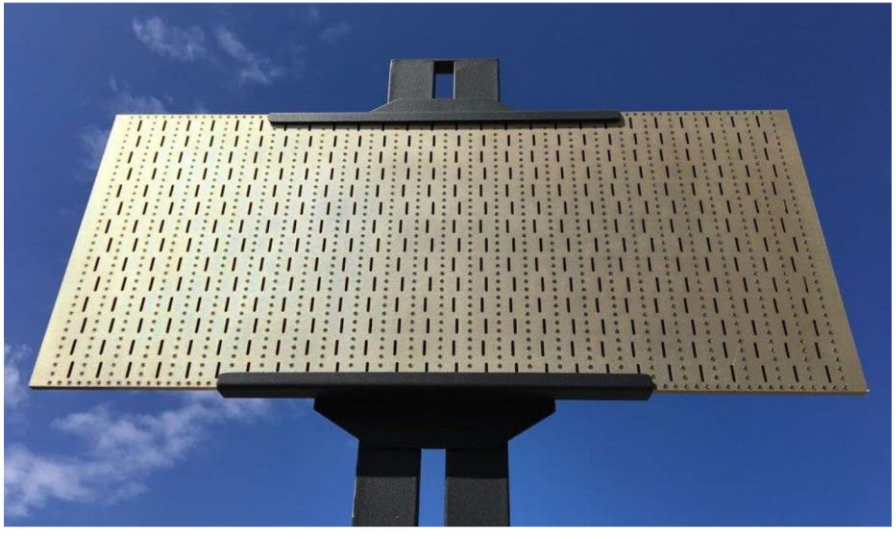
The problem of electronically steerable antennas based on active phased arrays



100s to 1000s of tiny RF circuits (MMIC)

- Each circuit is custom designed
- Each circuit costs a few euros
- Each circuit consumes a few Watts of power

The problem of electronically steerable antennas based on passive phased arrays

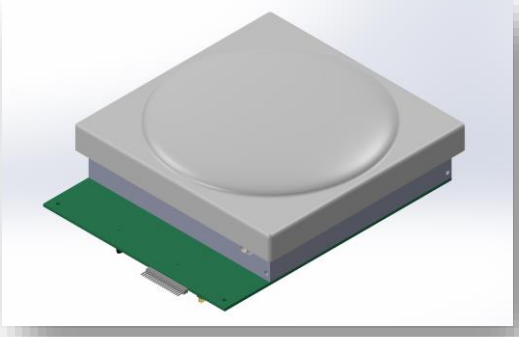


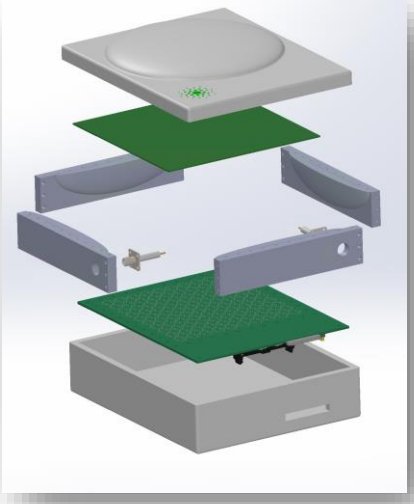
100s to 1000s of tiny antennas to feed

- Very dissipative RF lines
- Very dissipative controlling circuits or materials
- Exotic materials are not space compatible (LC…)

Greenerwave solution: an electronically reconfigurable leaky cavity antenna

Prototype
10 cm x 10 cm x 3 cm



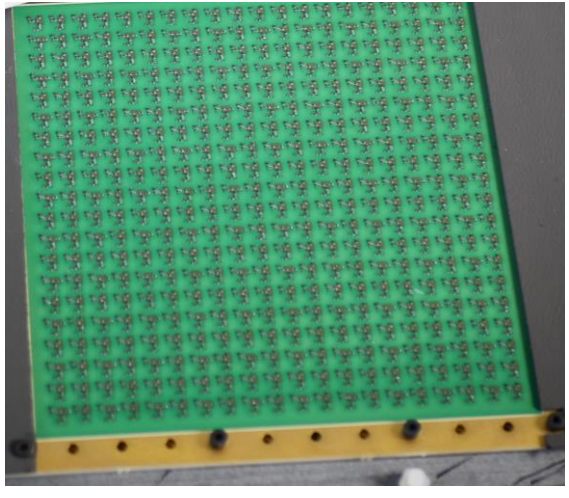


A disruptive and novel way of thinking wave emission

- **Waves** are **emitted inside a cavity** by a simple feed
- A **metasurface** is used to **passively control**, **only through reflections**, the wave field inside the cavity
- The **cavity leaks** through a transmittance mask, that further fine tunes the emission and radiation pattern

For the first time, waves are not emitted by a set of sources but by a whole cavity.
We do not generate RF signals with custom ICs, we simply shape electromagnetic waves.
Transposing the hardware complexity to software, we pave the way to low-consumption, ultrafast and ultra-efficient ESAs.

Passive beamforming using reflective technology



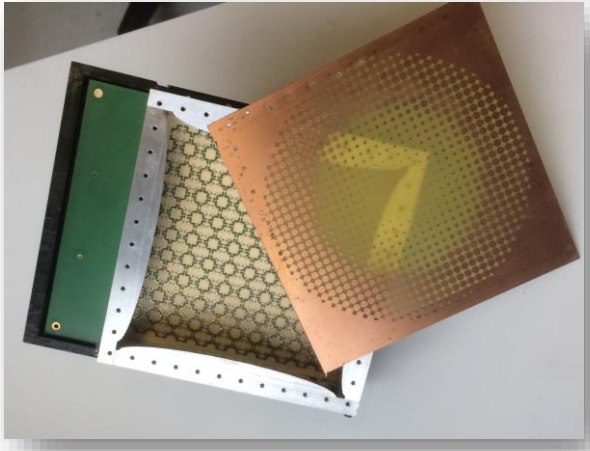
- Beamforming realized passively by controlling the reflections of waves
  => few Watts DC consumption
- No dissipative RF lines or materials
  => High efficiency (>40% target)
- Standard PCB technology with *off the shelves* components
  => Easy to spatialize

Fully software-controlled antenna using wave control

- Multibeam, multifeeds
  => Independent directions, frequencies, polarizations…
- Software controlled polarization
  => H, V, C, any…
- Full duplex with the same radiating aperture
  => No time multiplexing

Single feed metasurface controlled leaky cavity (coaxial or waveguide)

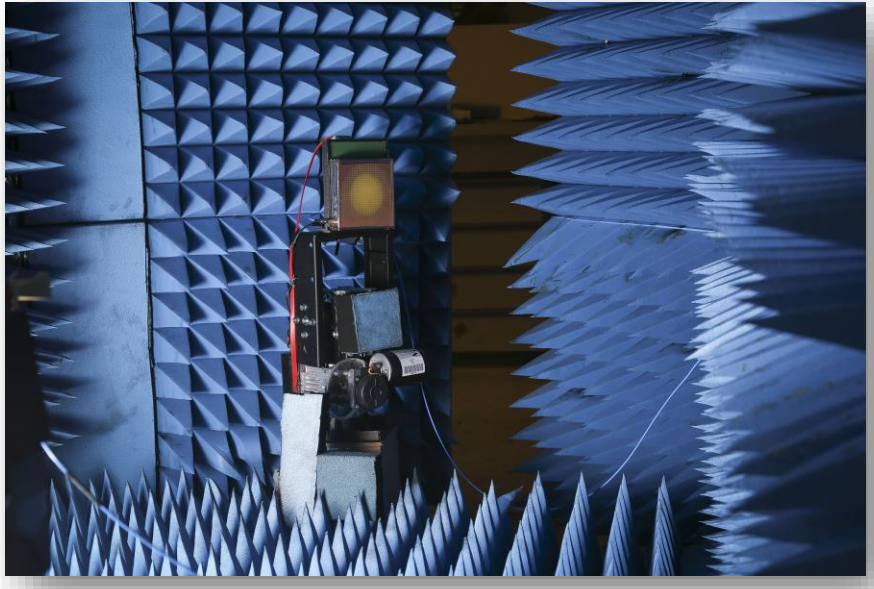
27-30GHz antenna



- Conformable to any shape
  => Tunable to scan needs
- Standard and protocol agnostic, due to wave control
  => Multiple protocols & starndards possible with same beamformer
- Compatible with any RF frontend
  => Easy upgrade up to 50 Watts RF

Results on our small scale beamformer at Ka

27-30GHz antenna

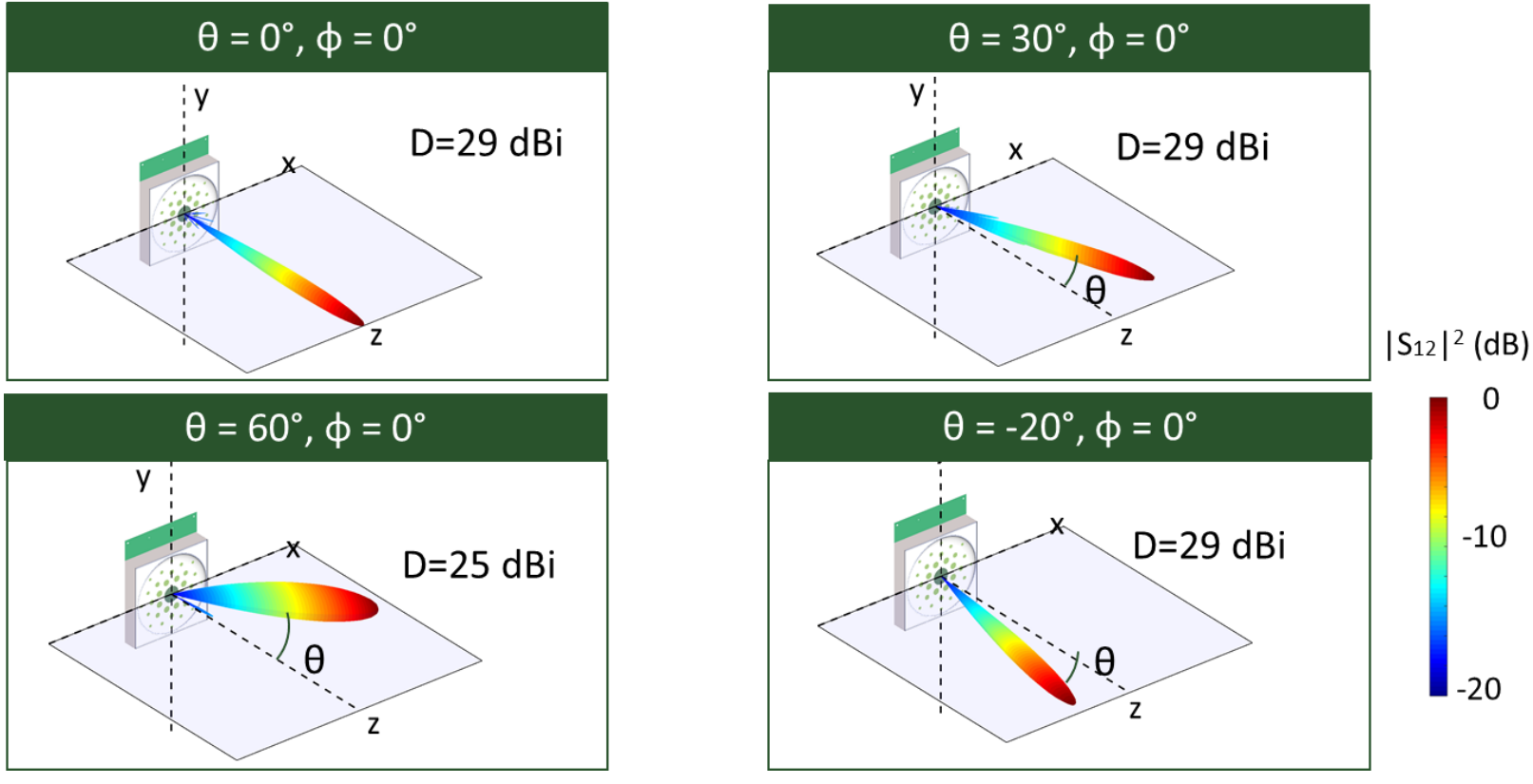


Prototype in anechoic chamber

Prototype described:

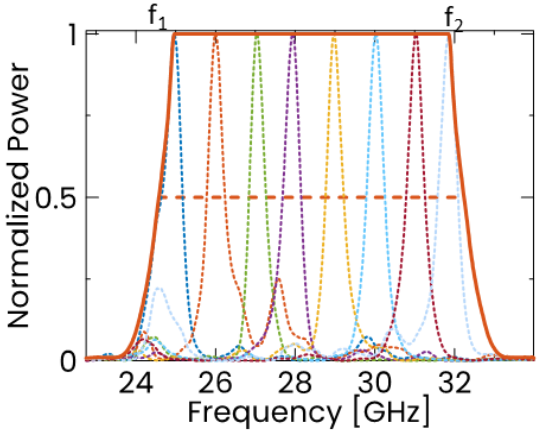
- Ka Tx beamformer
- 10cm*10cm*3cm, thickness can be optimized scalable
- 400 unit cells 5mm*5mm, 800 PIN diodes
- Real time reconfigurable

Electronically steerable antennas for mmWave based on tunable metasurface



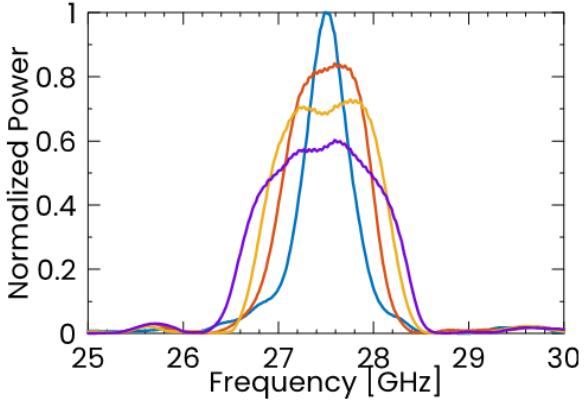
Unique software-controlled bandwidth properties

Total bandwidth

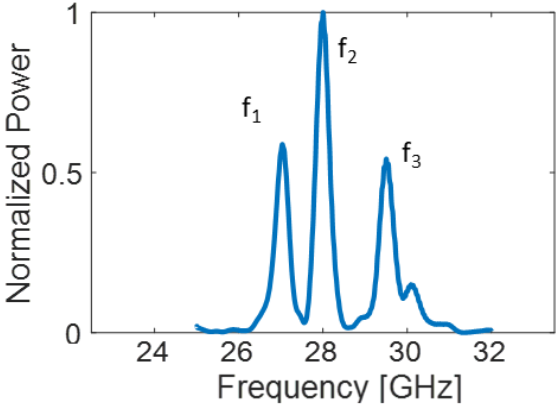


f_1 = 25 GHz,
f_2 = 32 GHz

Instantaneous bandwidth
(software controlled)



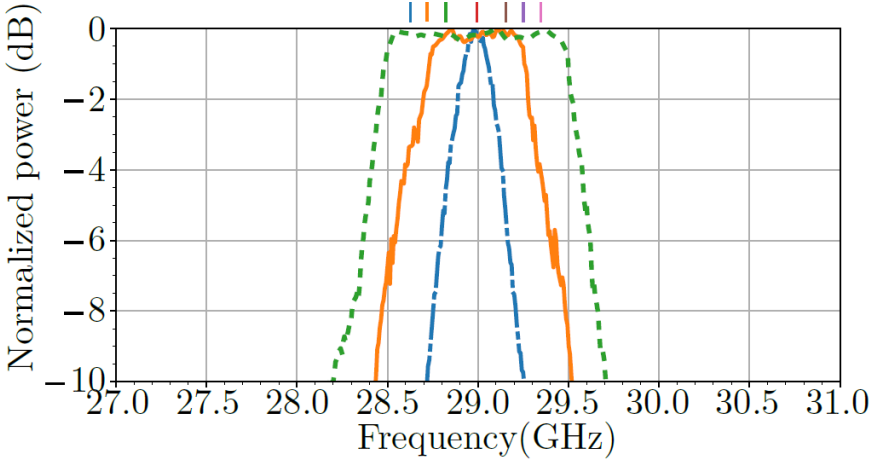
Operable frequencies
(software controlled)

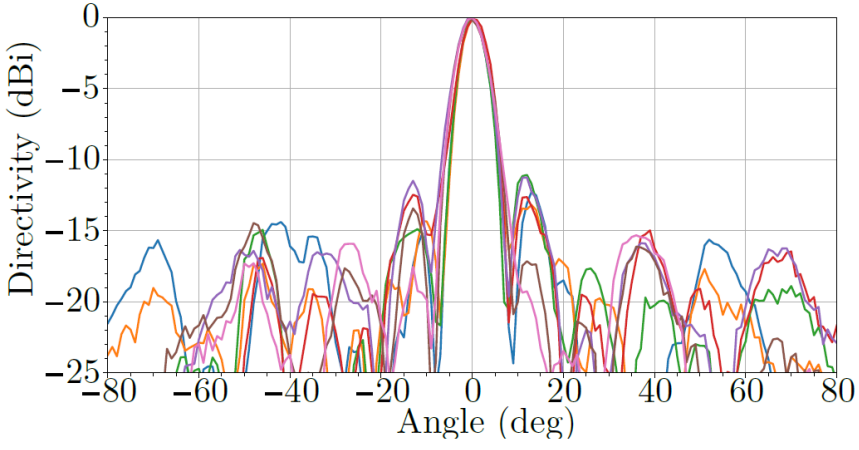


f_1 = 27 GHz
f_2 = 28 GHz
f_3 = 29.5 GHz

Currently working on Megaconstellation frequencies (Ka, Ku)
Easy transposition to telemetry bands, X band…

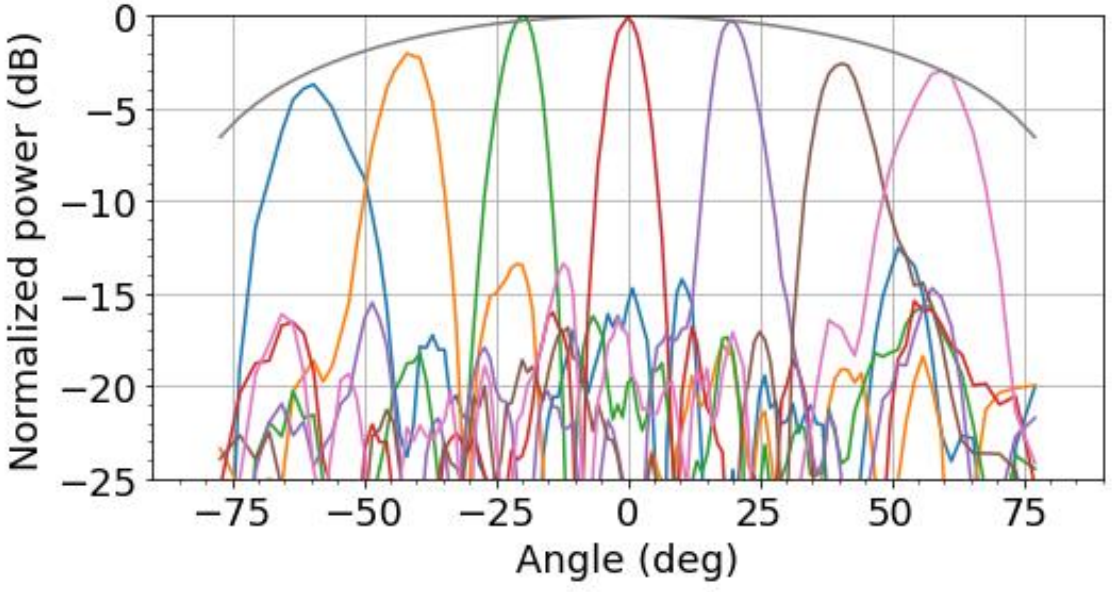
Ultra-wide instantaneous bandwidth without beam squint





Currently working on Megaconstellation frequencies (Ka, Ku)
Easy transposition to telemetry bands, X band…

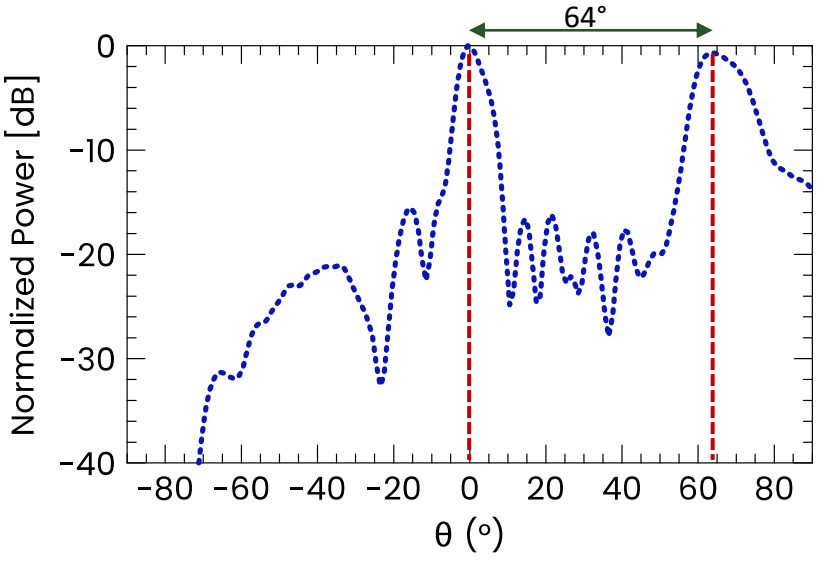
An antenna with almost ideal scan loss by design



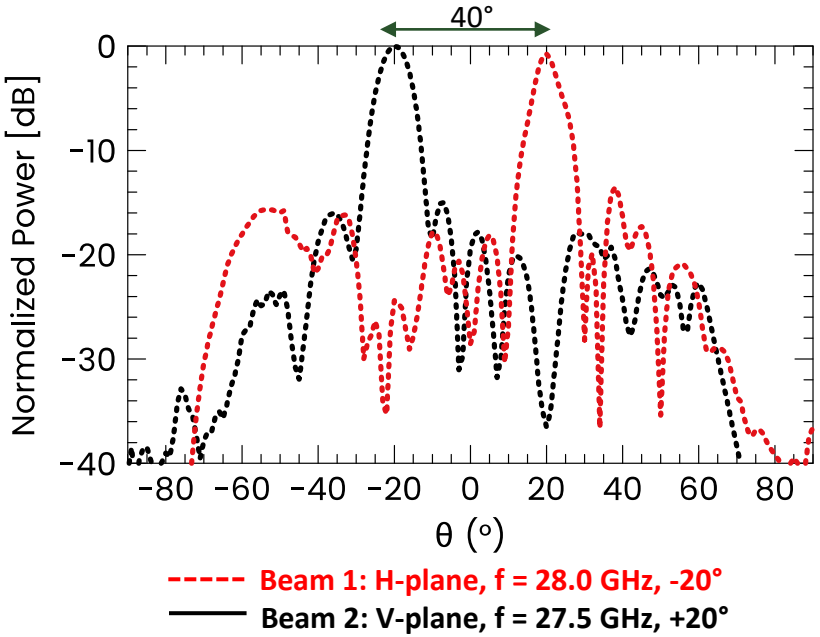
Scan loss can be optimized to needs by conforming the cavity shape

Multibeam, multibeam, flexibility

Co-polarized, same frequency beams



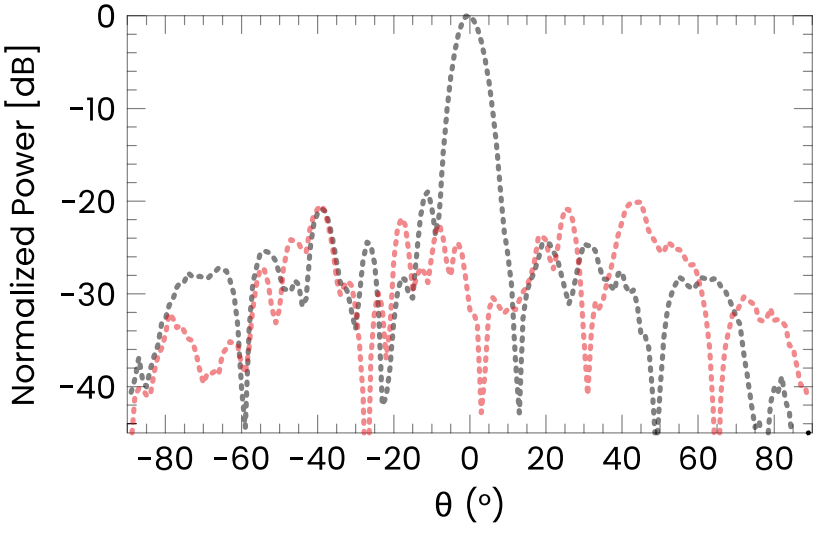
Cross-polarized, different frequencies beams



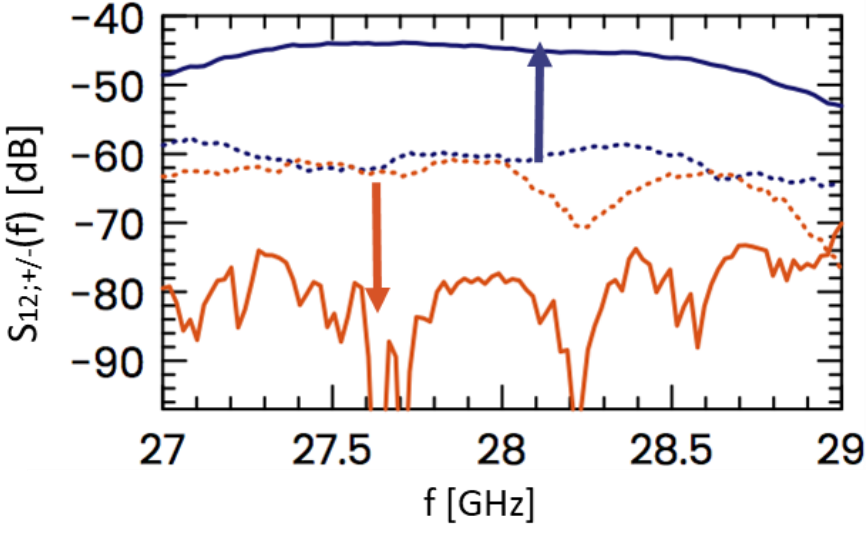
Up to 4 beams demonstrated in 10cm*10cm, emitted by 4 independent feeds

Software defined polarization

Co vs cross polarization, H and V (directivity)



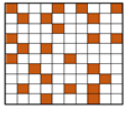
Co vs cross polarization, C+ and C- (Frequency)



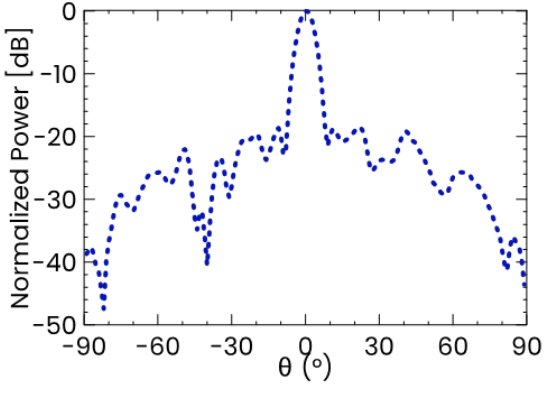
Using the same feed and beamformer, any polarization can be emitted in the far field

Decreasing the complexity even more, by removing pixels (i.e. controlled resonators)

Full number of pixels used

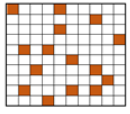


#pixels: 400
Pavement: Lambda/2

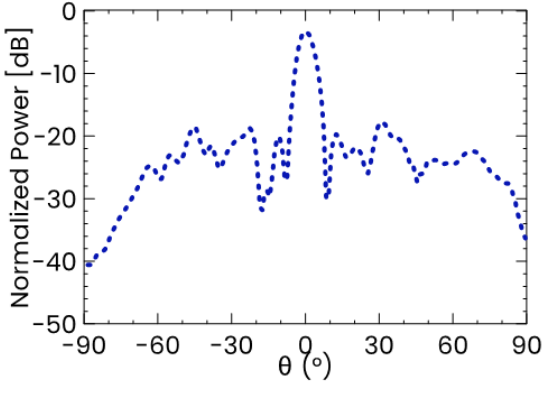


- Side Lobe Level: -20dB
- 3dB beamwidth: 5°

1/2 pixels used

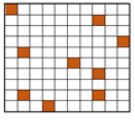


#pixels: 200
Pavement: Lambda/sqrt2

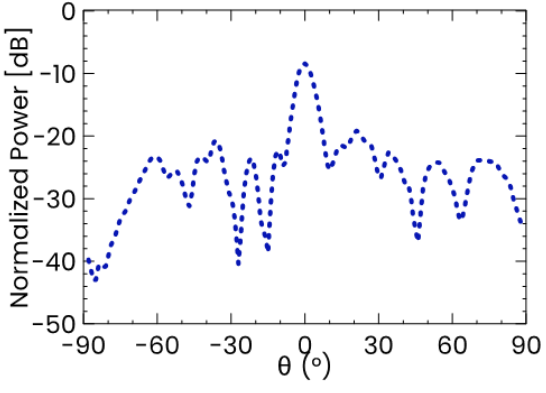


- Side Lobe Level: -15dB
- 3dB beamwidth: 6°

1/4 pixels used



#pixels: 100
Pavement: Lambda



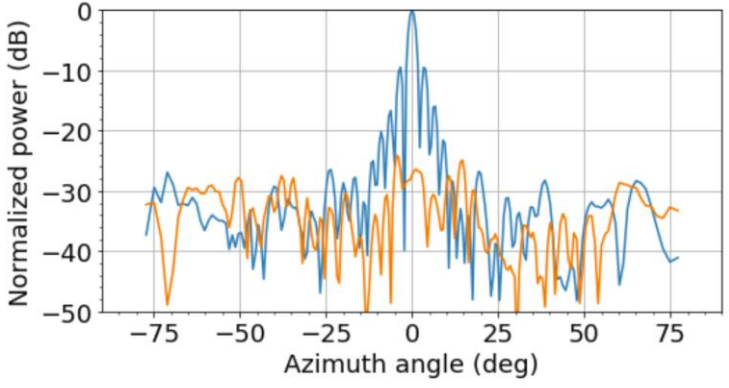
- Side Lobe Level: -11dB
- 3dB beamwidth: 6°

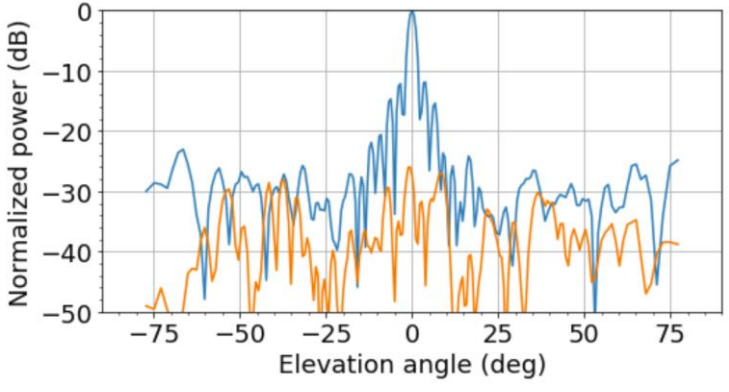
Possibility to do a beamformer with much smaller number of controlled resonators

We’re currently testing a scaled 30cm*30cm*3cm version for data link with French DGA

Concept is scalable to larger antennas

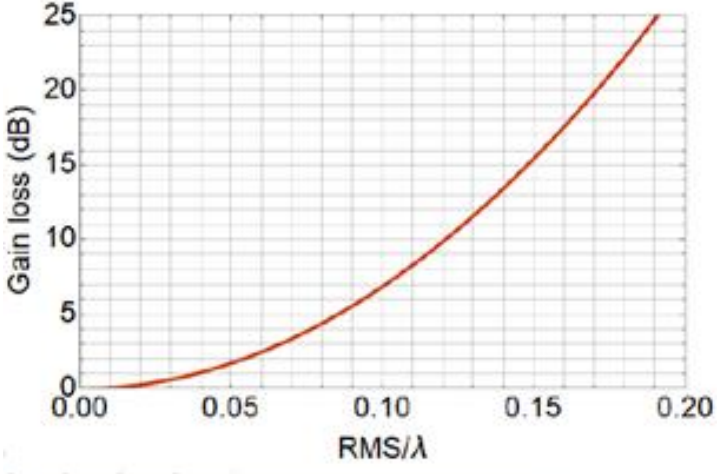
We’re currently testing a scaled 30cm*30cm*3cm version first radiation patterns





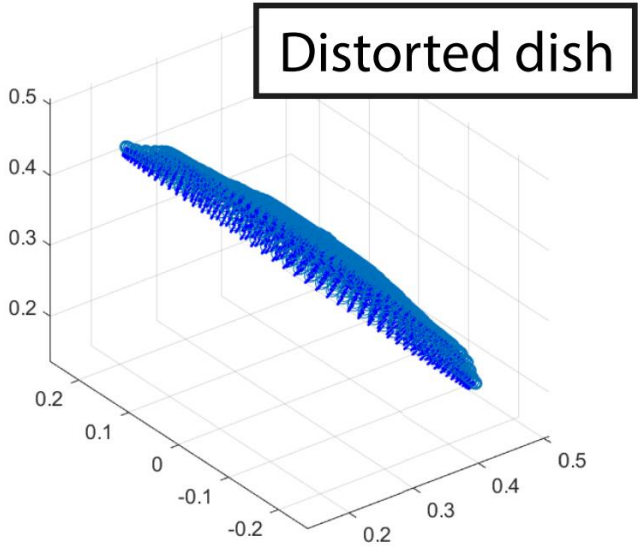
Concept is scalable to larger antennas

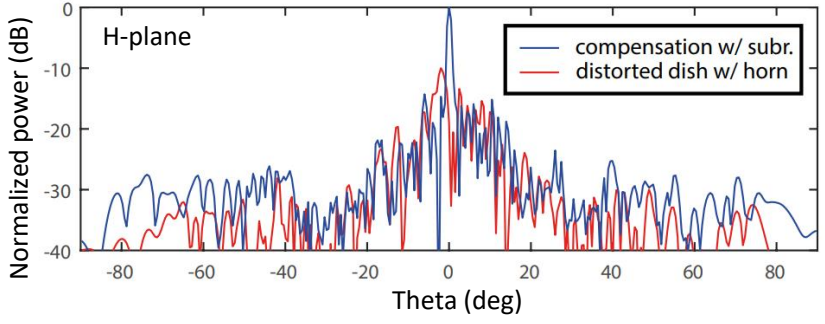
Alternative use: as sub-reflector in Cassegrain configuration for high frequencies (with CNES and Oxford Space Systems)

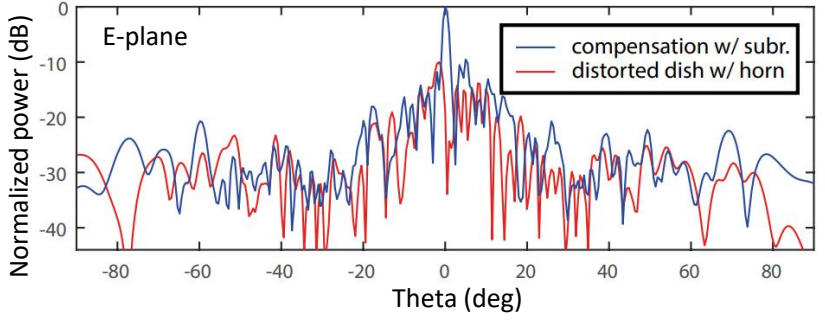


The higher the frequency the greater the impact of surface roughness

Alternative use: as sub-reflector in Cassegrain configuration for high frequencies (with CNES and Oxford Space Systems)

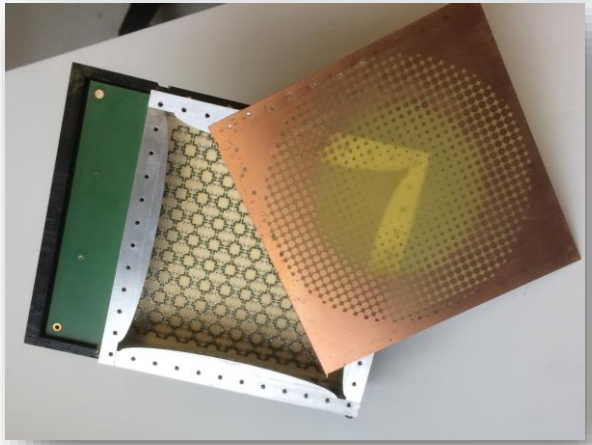






Dish imperfections can be mitigated, even large ones

THANK YOU!



- Currently tackling ground applications, but looking for IOD mission with CNES support

- Please reach out if you have any questions related to partnering, investing…

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